Bio-manufacturing for Space Applications (SynBio)

Completed Technology Project (2015 - 2019)

Project Introduction

Long-duration human exploration and habitation on other planets such as Mars will require not only bringing supplies, but also the ability to use local resources to manufacture needed mission products. *In situ* resource utilization and manufacturing can lead to substantial mass and volume savings, and increase mission self-sustainability. Example mission materials needed include food and nutrients, polymers (plastics), medicines, fuels, binders and various feedstock chemicals.

The overarching goal of this project is to develop and demonstrate advanced biological systems that utilize local resources to manufacture high-value products on demand. In many cases, biological systems are either cheaper than competing physico-chemical systems or are the only known method of production. A major project task includes developing methods that efficiently and rapidly convert carbon dioxide and hydrogen to organic substrates that microbes can use to grow and make mission products. Carbon dioxide is the primary component of the Martian atmosphere and is therefore an abundant source of carbon and oxygen. Hydrogen can also be obtained from locally-sourced water. Together, these molecules can form the basis for a wide array of products that support human missions.

Another major goal of this project is to demonstrate the ability to engineer microorganisms that produce human nutrients on-demand. Providing nutrition on long-duration missions via stored dehydrated food or by growing plants may lead to deficiencies in certain vitamins/nutrients. We are therefore demonstrating the capability to rapidly generate a specific carotenoid (an anti-oxidant) using an engineered yeast grown on an edible dehydrated media. This includes an initial demonstration on the International Space Station over the course of several years to investigate long-duration storage of the microbes and media, and the ability to produce a nutrient of consistent quality and quantity.

These efforts seek to leverage the rapidly increasing capabilities being developed in the private sector, academia, and National Laboratories regarding genetic engineering, bioinformatics, advanced manufacturing and processing, and chemical engineering techniques. Together, with intentional collaboration, these research areas will spur novel technologies that facilitate microbial bio-manufacturing in space and on Earth.

This AES project was transferred to the NASA Space Technology Mission Directorate (STMD) as of October 2020.

Anticipated Benefits

The ability to utilize biological systems to enable on-demand manufacturing of mission-relevant products using local resources is likely required to enable future long-duration missions. For example, a crew living on Mars for multiple

Bio-manufacturing for Space Applications

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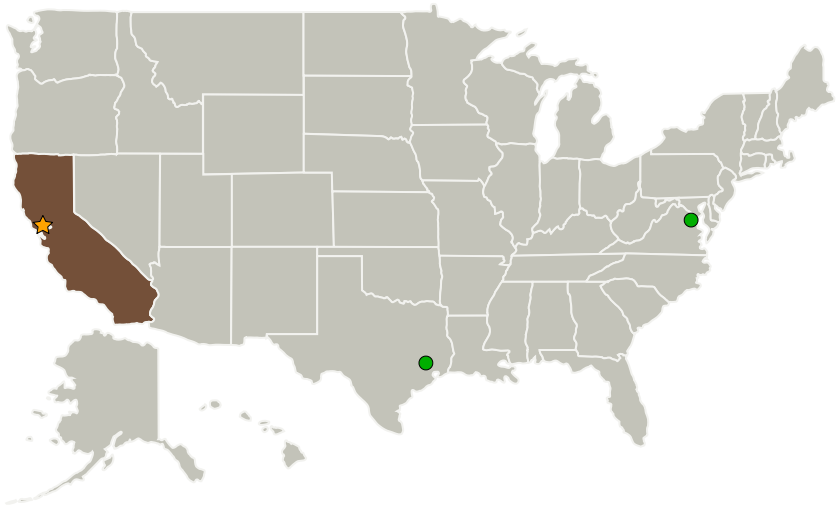
years will have no or minimal chance of resupply. Therefore, everything needed on the mission must either be launched with the crew, or made on-site. Items that have short shelf-lives, such as some vitamins and medicines, may be effectively useless during later stages of the mission. Being able to make these products quickly and reliably will be of critical importance. Additionally, making bulk-quantity materials for habitat construction and operation using local feedstock could substantially increase mission duration, cost-effectiveness, and reliability.

Advanced Bio-manufacturing techniques will also provide substantial benefit to the terrestrial economy. The rising economic and environmental costs of using fossil fuels and biomass as feedstock for the chemical synthesis of global goods is compelling the development of sustainable synthesis methods. Using atmospheric or waste carbon dioxide in combination with renewable energy sources to drive Bio-manufacturing is an alternate method that could revolutionize future Earth-based manufacturing systems. This overarching enterprise will require advancements in the current state of science and industry, and a convergence of the life and physical sciences and engineering, which will lead to completely new molecules with novel functions and properties, innovative applications, job creation, and productivity increases.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Exploration Systems Development Mission Directorate (ESDMD)

Lead Center / Facility:

Ames Research Center (ARC)

Responsible Program:

Exploration Capabilities

Project Management

Program Director:

Christopher L Moore

Project Manager:

Jitendra A Joshi

Principal Investigator:

John A Hogan

Co-Investigator:

Matthew Kanan

Exploration Capabilities

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Organizations Performing Work	Role	Type	Location
Ames Research Center(ARC)	Lead Organization	NASA Center	Moffett Field, California
Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas
NASA Headquarters(HQ)	Supporting Organization	NASA Center	Washington, District of Columbia

Primary U.S. Work Locations
California

Project Transitions

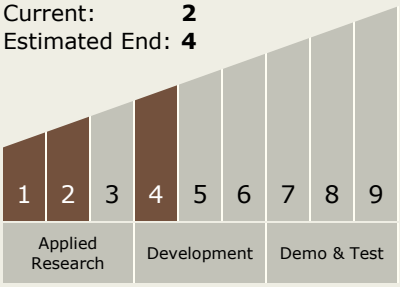
October 2015: Project Start

September 2019: Closed out

Closeout Summary: This AES project was transferred to the NASA Space Technology Mission Directorate (STMD) as of October 2020. Synthetic Biology Application (SynBio) and Bio-manufacturing for Space Applications are one and the same. Project goes by both names.

Technology Maturity (TRL)

Start: **1**
Current: **2**
Estimated End: **4**



Technology Areas

Primary:

- TX07 Exploration Destination Systems
  - TX07.2 Mission Infrastructure, Sustainability, and Supportability
    - TX07.2.1 Logistics Management

Target Destinations

The Moon, Mars

Supported Mission Type

Projected Mission (Pull)